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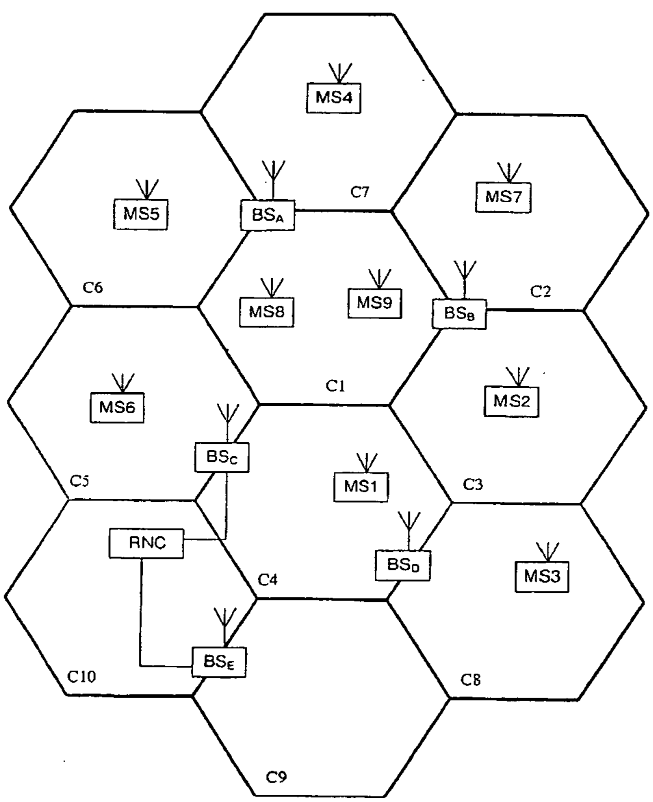
(54) Title: METHOD AND ARRANGEMENT OF TRANSMITTING INFORMATION IN A TELECOMMUNICATIONS SYSTEM



(57) Abstract: A method and arrangement providing separate system optimization in a cellular radio communication system comprising at least two Node:s and a mobile station, in order to improve the total Quality of Service provided by the network during the performance of a soft handover operation between cells belonging to two different Node b and a softer handover operation between cells belonging to the same Node b, respectively. Therefore, as in a CDMA-based radio access system, the mobile stations are spending a large amount of time in soft handover, a separate system optimization contribute to a better exploitation of the available radio resources.

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METHOD AND ARRANGEMENT OF TRANSMITTING INFORMATION IN A TELECOMMUNICATIONS SYSTEM

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FIELD OF INVENTION

The present invention relates to a method and arrangement in a wireless communication system, such as a cellular communication system, which includes mobile radio communication stations. More particularly, the present invention relates to a method and arrangement for better usage of available radio resources in CDMA and WCDMA system.

DESCRIPTION OF RELATED ART

Fig. 1 illustrates ten cells C1-C10 in a typical cellular mobile radio communication CDMA-system. Normally a cellular mobile radio communication system would be implemented with more than ten cells. Each cell, C1-C10, is related to at least a logical base station, called Node B in the 3GPP standard specification. The Node b BS_A covers the cells C1, C6, C7. The Node b BS_B covers the cells C1, C2, C3. The Node b BS_C covers the cells C4, C5. The Node b BS_D covers the cells C4, C8. The Node b BS_E covers the cells C9, C10. Fig. 1 illustrates the Node b as situated at the cell border and provided with two or three antennas. Fig. 1 also illustrates nine mobile stations MS1-MS9 which are movable within the cells and from one cell to another. In this disclosure, a mobile station is defined as any mobile station, e.g. e mobile phone or a mobile computer provided with equipment for wireless communication. In a typical cellular mobile radio communication system there would normally be more Node b and mobile stations. In fact, there is typically many times the number of mobile stations as there are Node b.

Also illustrated in fig. 1 is a radio network controller RNC. The RNC illustrated in fig. 1 is connected to all five Node b BS_A-BS_E by cables or trunk lines, only a few of the cables being shown in the figure. The interface between a RNC and a Node b is also called Iub interface. The radio network controller RNC is connected to the Core Network CN through an Iu interface. The Iu interface is not shown. The RNC selects the cell, which is to be inserted in the active set of a mobile

station. The active set is the set of cells connected simultaneously to a given mobile station. A Core Network is the network connected to a set of RNC, e.g. a fixed network.

In addition to the radio network controller RNC illustrated in fig. 1, there may be other RNCs connected by cables or fixed radio links to the Node b, called Iub interface. A Node b is connected to one and only one RNC. The radio network controller RNC, the Node b, and the mobile stations are all computer-controlled. Each RNC is responsible for the resources in its set of Node b. Two or more RNCs may be interconnected by means of an Iur interface. An Iur interface can be conveyed over direct physical connection between two or more RNCs or virtual networks using any suitable transport network. An Iur interface is an interface, which allows soft handover between different RNCs. The term soft handover will be disclosed below. Iu and Iur are logical interfaces.

Current digital cellular systems employ Node b, which separate the communications with mobile stations using time, frequency or code separation, or combinations thereof. A System employing code separation is called a CDMA system. The transmission of signals from a mobile station to a Node b is called uplink. The transmission of signals from a Node b to a mobile station is called downlink. Three main resources are managed in a radio access system using CDMA technology:

- Interference in uplink due to power transmitted in the uplink
- Power. Soft handover implies that the mobile station is power controlled by several cells on the uplink or that several cells are power controlled by one mobile station on the downlink
- Code, i.e. OVSF (Orthogonal Variable Spreading Factor) codes in downlink. The use of OVSF codes preserve orthogonality between downlink physical channels of different rates and spreading factors.

Soft handover is a handover operation in which one mobile station MS1 simultaneously communicates with several cells, e.g. C1, C2 and C3. A soft handover is seamless and no information is lost during the handover process. For transmission uplink, when

performing a soft handover operation, two or more Nodes b receive a signal from the mobile station, whereupon the signal is combined in the network. Normally, selection combining is used if the two cells belong to different Nodes b. For transmission downlink, when performing a soft handover operation, a mobile station receives a signal from two or more base stations, whereupon the signal is combined in the receiver, e.g. a rake receiver, of the mobile station. Normally, maximum ratio combining (MRC) is used. A RAKE-receiver performs a correlation of receivers called fingers. A finger is reserved for each path in order to provide diversity between multi-path components. Each finger is synchronized to one path. A rake finger picks up one multi-path component and suppresses the other. Normally, a maximum ratio combining (MRC) is output from the RAKE-receiver. In the uplink, selection combining is performed in the radio network controller (RNC), when the mobile station is connected to different Nodes b (BS_A, BS_B). The transmitted signal from the mobile station is received and decoded in all connected Node b (BS_A, BS_B) and the signal power data is sent to the RNC.

A softer handover is a handover process performed between two cells (C6, C7) belonging to the same Node b (BS_A). A softer handover operation entails less signaling in the network than a soft handover operation. In the uplink, combining can be performed in the rake receiver of the Node b instead of in the network. Maximum ratio combining may be used in both uplink and downlink.

The set of cells to which a mobile station is connected is called the active set (AS). A mobile station can use different base station or nodes b on the uplink and downlink, respectively. Soft handover can thus be performed on the uplink and downlink, respectively. An important soft handover parameter is the Add threshold parameter. The Add threshold parameter is a threshold value based on which decision is taken, by a RNC, if a given cell can be inserted in the active set (AS) or not. A given cell C6 is inserted in the active set if the difference between the best received signal power and the power of the

signal received from the cell C6 is higher than the Add threshold value. The best received signal power is the signal having the maximum power received from the cells in the active set. The power is evaluated at the mobile station on the downlink and is typically measured on a primary common pilot channel (CPICH). The active set includes the best cell and at least a further cell having the above mentioned power difference higher than the Add threshold parameter, if the terminal is in soft handover. However, the maximum amount of cells in the active set limits the number of connected cells. The Add threshold parameter and the maximum number of cells in the active set determines the number of cells that are involved in a soft/softer handover process in the system. If the Add threshold parameter value is small, the precentage of users in soft/softer handover will be small and vice versa.

The trade-off between capacity, quality and coverage for system according to the WCDMA standard in downlink and uplink have been studied. The studies indicate different limiting factors on the downlink and the uplink.

The above disclosed studies show that soft handover (SHO) always increases system capacity on the uplink: more active links, i.e. link in communication, lead to a better uplink capacity. This is mainly due to the fact that on the uplink, the interference does not depend on the number of cells present in the active set (AS). A man skilled in the art understands that a trade-off between a large number of cells in the active set, a good quality on the uplink, increased signaling load over the air interface and the transport network must be considered. The signaling aspects for the link between the Node b and the RNC, the Iub interface, for the link between two RNC, the Iur, and the UTRAN (Universal mobile telecommunications systems. Terrestial Radio Access Network) and the core network CN are not considered.

Different studies show that soft handover on the downlink increases system capacity only when specific values on the handover parameters are used. Furthermore, the influence of those parameters depends on the system load. In the case of high

traffic load on the downlink, it is better to have a reduced number of cells in the active set in order to reduce the total interference. In the case of a low traffic load, the benefit of using soft handover increases as the number of cells in the active set or transmission resources in the downlink increase until a threshold value is reached. This phenomenon is due to the fact that the advantage of using soft handover on the downlink is counterbalanced by additional interference caused by multiple transmission.

A mobile station executes power control commands received from the cell that requires the minimum amount of output power. Therefore, the probability of transmitting at a minimum power level, given a certain quality requirement, increases with the number of cells in the active set. I.e., the more cells there are in the active set, the greater is the probability that one or more of these has a minimum absolute power. However, when transmitting in the downlink, every cell in the active set is transmitting, and thus the interference is increased. Thus, when transmitting in the downlink, there is a trade off between the advantages of performing a soft handover operation on a CDMA system and increased interference. Another important factor is the transmission resources in the fixed network. For a mobile station MS1 in soft handover, all connected Node b (BS_A, BS_B) belonging to different cells, require a transmission link to the Radio Network Controller RNC. Thus, a large percentage of mobile stations in soft handover will require a large amount of extra transmission resources in the access network. The RNC controls every soft handover process that take place in a Node b.

The soft handover procedure is composed of a number of single functions:

- Measurements
- Filtering the measurements
- Reporting the result of the measurements
- The soft handover algorithm
- Execution of handover

Based on the measurements of the set of monitored cells, the soft handover function evaluates if any cell should be added to, removed from, or replaced in the active set.

The conference paper written by Magnus Karlsson et. al. "Evaluation of Handover Algorithms for Packet transmission in WCDMA" presented in Proceedings of IEEE, Houston, USA, May 17-21, 1999 discloses how soft handover in a CDMA system affects the performance of a radio communication system in both the uplink and the downlink. Results presented in said conference paper intimates that for transmission downlink, the advantage of soft handover depends on the characteristics of the radio channel. The largest gain is achieved for channels having limited multipath propagation. For transmission uplink, soft handover is essential in order to provide a good system capacity. However, a disadvantage of soft handover is increased transmission load in the access network.

In a CDMA and WCDMA system, the transmission uplink uses I/Q/code multiplexing for user data and control information for physical layer. The physical layer control information is carried by the Dedicated Physical Control Channel (DPCCH) having a fixed spreading factor of 256. The higher layer information, including user data, is carried on one or more Dedicated Physical Data Channels (DPDCHs), having a spreading factor ranging from 4 to 256. The uplink transmission may consist of one or more Dedicated Physical Data channels (DPDCH) having a variable spreading factor, and a single dedicated Physical Control Channel (DPCCH) having a fixed spreading factor.

The DPDCH data rate may vary on a frame-by-frame basis. The DPDCH data is transmitted continuously and rate information is transmitted using a Transport Format Combination Indicator(TFCI) and DPCCH information related to the data rate on the current DPDCH frame. If the TFCI is not decoded correctly, the whole data frame is lost. Because the TFCI indicates the transport format of the same frame, the loss of TFCI does not affect any other frames. The reliability of the TFCI is higher than the reliability of the user data detection on the DPDCH. Therefore, the loss of TFCI is a rare event.

The uplink DPCCH uses a slot structure having 15 slots over a radio frame of 10 milliseconds. This results in a slot duration of 2560 chips or about 666 microseconds. This is close to the burst duration of 577 microseconds according to the GSM specification. Each slot is provided with four fields allocated for pilot bits, TFCI, Transmission Power Control (TPC) bits and Feedback Information(FBI) bits. The pilot bits are used for estimating the channel condition at the receiver end, and the TPC bits carry power control commands used by the Node b for the downlink power control.

In the technical specification for 3rd Generation mobile telephone system 3GGP RAN WG2, 25.922 VER 0.5.0, "Radio Resource Management Strategies", a method called Site Selection diversity Transmit Power Control (SSDT) is disclosed. SSDT is a method for power control for the downlink that can be applied while a mobile station is in soft handover in order to reduce the interference on the downlink. The principle of SSDT is that the best cell (C1) in the active set (C1, C2, C3) is dynamically chosen as the transmitting Node b (C1), and the other Node b (C2, C3) in the active set turns off their Dedicated Physical Data Channel (DPDCH). Only one cell transmits data, but all cells transmit power control information, and other type of control information. The principle of DPDCH is disclosed in more detail in the above mentioned conference paper written by Magnus Karlsson. The Dedicated Physical Control Channel (DPCCH) is transmitted as usual. Each Node b is given a temporary identification number. Computer simulations have been carried out in order to investigate the behavior of SSDT under ETSI & ITU-R guidelines for IMT-2000RTT evaluation. The results are compared to a conventional power control method, where the transmit power of all involved cells is controlled in order to reach a predetermined value for the Signal-to-Interference Ratio (SIR). The simulations show that SSDT is superior to normal soft handover at low speed, increasing transmitting capacity by means of a reduced total interference. The capacity is enhanced by approximately 40% without diversity at the mobile station, and 50% with diversity at the mobile station, when transported at a

Fig. 2 is a diagram illustrating simulation results obtained using different Add threshold values.

DETAILED DESCRIPTION

In a radio communication system according to Fig. 1, the links between mobile stations and Node b are established as follows:

- A mobile station MS1 and a Node b BS_A perform measurements on the cells belonging to an active set, i.e. the set of cells (C1, C2, C3, C4, C5) being active during the soft handover operation.
- The mobile station MS1 and the Node b BS_A evaluate the result from these measurements with respect to specific events, such as loss of connection, or when the received power, measured on a common pilot channel (CPICH) from a cell of an active set exceeds a predefined threshold value (Add threshold).
- The measurements reports are transmitted to the radio network controller RNC.
- The radio network controller RNC uses a handover evaluation procedure in order to take a final decision on which cells to add, delete or replace in the active set.

A cell that has been inserted in the Active Set of a certain mobile station transmits data information on the DPDCH and control information on the DPCCH to the mobile station on the downlink. The cell receives data from the mobile station on the uplink. Therefore, the radio network controller RNC uses the same algorithm and the same parameters when selecting cells that are to be inserted in the active set of a certain mobile station.

In order to attend to the above disclosed problems, the radio network controller RNC uses different algorithms for selecting a cell to be used for transmission uplink or downlink, respectively, to a determined mobile station MS1. The radio network controller RNC can also use the same algorithm for selecting a cell to be used for transmission on the uplink and for transmission on the downlink, but uses different parameters or predetermined threshold values for selecting said cell. The cell that has been selected for transmission on the downlink,

will transmit both control and data information, whereas the cell that has been selected for transmission on the uplink transmits only control information in order to reduce the power consumption of the cell.

Two separate active sets of cells belongin to the same or different Node b, i.e. the sets of active links are considered, one set for transmission uplink (upAS), and one set for transmission downlink (dlAS). As an example, the Active Set comprises five cells (C1, C2, C3, C4, C5), the active set for the downlink (dlAS) comprises three cell (C1, C2, C3) and the active set for the uplink (upAS) comprises five cells (C1, C2, C3, C4, C5). The cells in the active set for transmission downlink transmit both on the control channel DPCCH and the data channel DPDCH, and the cells receive data and speech from the mobile station MS1 on the uplink. The cells in the active set for transmission uplink transmit on the control channel DPCCH on the downlink and receive data and speech from the mobile station MS1 on the uplink. In order to implement the above disclosed method the construction of the RNC only require minor changes, since it has only to set and control different active sets for transmission uplink and downlink, respectively. Possibly some changes in the code allocation and spreading factor selection for the control channels enable the reduction of code tree occupancy.

By introducing two setS of active links, one for the uplink, and one for the downlink, the mobile station takes advantage from a large number of links on the uplink, which increase the performance of soft/softer handover on the uplink, while reducing the amount of data information transmitted on the downlink, as only relevant data is transmitted. The reduced interference on the downlink results in a reduction of transmitted power.

Each cell in the Active Set (upAS and dlAS) continues to transmit control information, e.g. Transmit Power Control (TPC) on the Dedicated Physical Control Channel (DPCCH) in both directions.

The above method is an evolution of the SSDT method disclosed above. However, the object of the above method is to provide different management of active links for transmission on the uplink and the downlink, respectively. The object of the SSDT method is to transmit downlink only from the best cell while in soft/softer handover, in order to reduce the interference for transmission on the downlink, but to the cost of no advantage of using maximum ratio combining MRC. According to a SSDT method, there is only one signal from one cell, and no maximum ratio combining (MRC) is performed.

According to one method of implementing asymmetric active set for transmission on the uplink and the downlink, respectively, different predetermined thresholds are used. Said threshold values are separately tuned for the uplink and the downlink. For example, the radio network controller RNC applies the same handover evaluation procedure but uses different threshold values for transmission on the uplink and downlink, respectively.

According to a further embodiment of the invention, the predetermined threshold values for performing soft/softer handover are dynamically set depending on the traffic load conditions. The usage of different values for the "Add Threshold" parameter can be advantageous for the total system quality. E.g., the Add Threshold parameter can be load depending. I.e. different values of the Add Threshold parameter are used for performing a soft/softer handover operation depending on the traffic load in the system. As disclosed above, the advantages of performing a soft/softer handover operation for transmission on the downlink are entirely dependent on the traffic load in the system or the cell. In order to optimize the radio resources, the number of active links for transmission on the downlink should be reduced, i.e. a reduced active set in the downlink (dlAS), when the system or cell gets more loaded.

However, even when a system is heavily loaded with traffic, transmission on the uplink is not affected negatively of a large active set for transmission on the uplink. The above observation leads to the conclusion that a dynamic adaptive, i.e. load

depending value for the Add threshold parameter for transmission downlink and a large value for the Add threshold parameter for transmission downlink is favorable. In order to take into account different traffic loads for each cell, the value for the Add threshold parameter may be different for each cell or Node b.

An exemplary algorithm for a load dependent value for Add Threshold is

$$\text{Add\_th\_dl} = A\exp\left[-(\max(Pdl_j) - mean(Pdl_j)) \Big/ (limitPdl - \max(Pdl_j)) \right]$$

for transmission downlink, and Add_th_ul = B for transmission uplink, wherein

- A and B are constant values that are optained by means of computer simulations and thereafter tuned according to empiric data.
- $\max(Pdl_j)$ is defined as the value for maximum power. The maximum power is defined as the power transmitted by a cell on the downlink under a predefined time period.
- $mean(Pdl_j)$ is the mean value of the output power from all the considered cells on the downlink.
- limit Pdl is the power limit for one cell on the downlink. Power limit is here defined as the total power available for each cell. When the power on the downlink is close to the limit or is far from the mean value, the value of Add threshold is small.

Fig. 2 is a diagram illustrating the above disclosed algorithm 5 in an urban environment, wherein A=4, B=9dB and limit Pdl= 17W.

CLAIMS

1. A method of transmitting information in a cellular radio communication system, comprising at least two Node:s b, each node covering a respective set of cells and a mobile station, the method comprising the steps of

- performing a soft handover operation of the mobile station from a first cell to a second cell, characterized in that
- different active sets of cells are selected for transmission downlink (dlAS) and uplink (upAS), respectively, during the soft handover operation in order to optimize the radio resources.

2. A method according to claim 1, characterized in that the cells in the active sets for transmission downlink (dlAS) and uplink (upAS), respectively, belongs to different Node:s b.

3. A method according to claim 1, characterized in that the cells in the active sets for transmission downlink (dlAS) and uplink (upAS), respectively, belongs to the same Node b.

4. A method according to any of claims 1-3, characterized in that different predetermined threshold values (Add threshold) pertaining to connection quality are used when performing the selection of the active sets for transmission uplink (upAS) and downlink (dlAS), respectively.

5. A method according to claim 4, characterized in that the predetermined threshold values used for selecting the active sets for transmission uplink (upAS) and downlink (dlAS), respectively, are dynamically set depending on the traffic load conditions.

6. A method according to claim 5, characterized in that the amount of cells in the active set of cells for transmission downlink (dlAS) is reduced when the traffic load is increased.

7. A method according to claim 4, characterized in that the predetermined threshold values used for selecting the active set for transmission uplink (upAS) and downlink (dlAS), respectively, are set individually for each cell in the active set (dlAS, upAS).

8. A method according to claim 4, characterized in that the predetermined threshold values used for selecting the cells

in the active set for transmission uplink are set to a constant value.

9. A method according to claim 5, characterized in that the predetermined threshold values used for selecting the cells in the active set for transmission downlink (dlAS), are set dynamically according to the following algorithm

$$\text{Add\_th\_dl} = A\exp\left[-(\max(Pdl_j) - mean(Pdl_j)) \Big/ (limitPdl - \max(Pdl_j)) \right]$$

wherein

- A is a constant value,
- $\max(\mathrm{Pdl}_j)$ is defined as the value for maximum power on the downlink,
- $\mathrm{mean}(\mathrm{Pdl}_j)$ is the mean value of the output power on the downlink, and
- limit Pdl is the power limit for one cell on the downlink.

10. A cellular radio communication system, comprising at least two Node:s b, each node covering a respective set of cells, and a mobile station, the system comprising means for

- performing a soft handover operation of the mobile station from a first cell to a second cell, characterized in that
- different sets of cells are selected for transmission downlink (dlAS) and uplink (dpAS), respectively, during the soft handover operation in order to optimize the radio resources.

11. A system according to claim 10, characterized in that the active sets of cells for transmission downlink (dlAS) and uplink (upAS), respectively, belongs to the different Node:s b.

12. A system according to claim 10, characterized in that the active sets of cells for transmission downlink (dlAS) and uplink (upAS), respectively, belongs to the same Node b.

13. A system according to any of claims 10-12, characterized in comprising means for using different predetermined threshold values (Add threshold) pertaining to connection quality for selecting the active set of cells for transmission uplink (upAS) and downlink (dlAS), respectively.

14. A system according to claim 13, characterized in comprising means for dynamically setting the predetermined

threshold values used for selecting the active set of cells for transmission uplink (upAS) and downlink (dlAS) depending on the traffic load conditions.

15. A system according to claim 14, characterized in comprising means for reducing the amount of cells in the active set of cells for transmission downlink (dlAS) when the traffic load is increased.

16. A system according to claim 13, characterized in comprising means for individually setting the predetermined threshold values (Add threshold), which are used for selecting the actives set of cells for transmission uplink (upAS) and the actives set of cells for transmission downlink (dlAS), for each cell in the active set (upAS, dlAS).

17. A system according to claim 13, characterized in comprising means for setting the predetermined threshold values (Add threshold) used for selecting the active set of cells for transmission uplink (upAS) to a constant value.

18. A system according to claim 14, characterized in comprising means for dynamically setting the predetermined threshold values (Add threshold) used for selecting the active set for transmission downlink (dlAS) according to the following algorithm

$$\text{Add\_th\_dl} = A\exp\left[-\left(\max(Pdl_j)-mean(Pdl_j)\right)\Big/\left(limitPdl-\max(Pdl_j)\right)\right]$$

wherein

- A is a constant value,
- $\max(Pdl_j)$ is defined as the value for maximum power on the downlink,
- $mean(Pdl_j)$ is the mean value of the output power on the downlink, and
- limit Pdl is the power limit for one cell on the downlink.

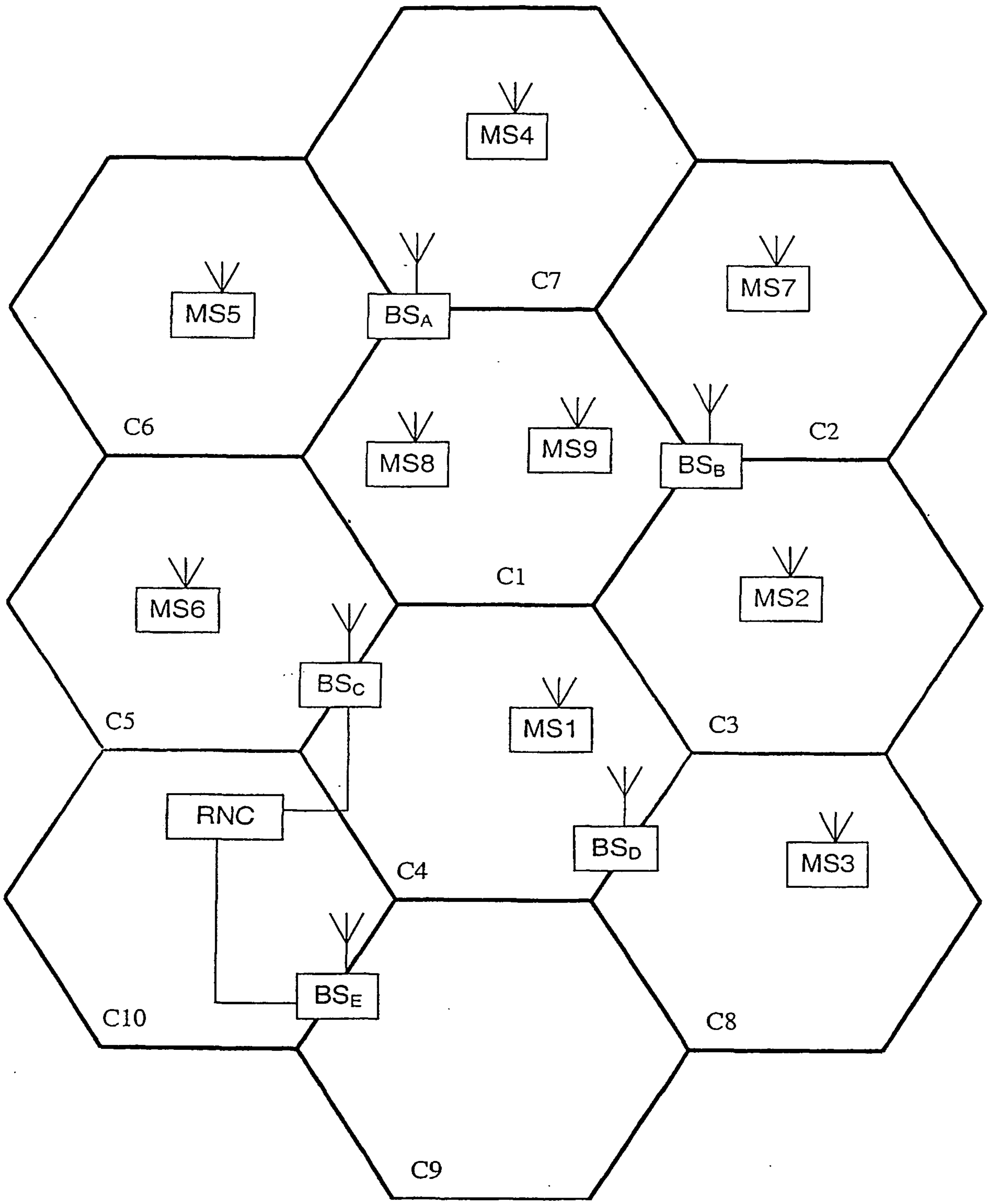
MS4
MS5
BSA
C7
MS7
C6
MS8
MS9
BSB
C2
MS6
C1
MS2
BSC
C5
MS1
C3
RNC
BSD
MS3
C4
BSE
C10
C8
C9

Fig. 1

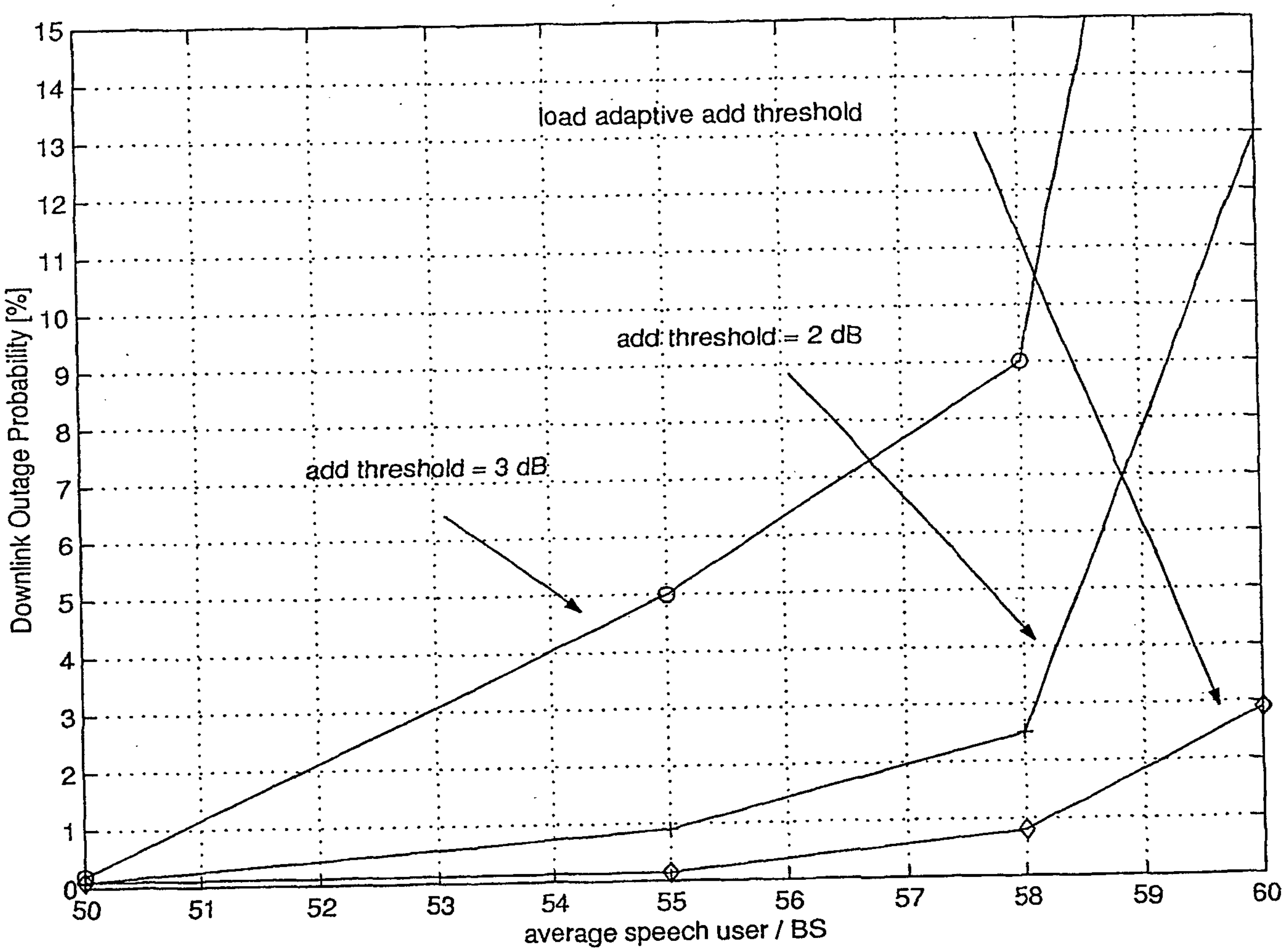
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
Downlink Outage Probability [%]
load adaptive add threshold
add threshold = 2 dB
add threshold = 3 dB
50
51
52
53
54
55
56
57
58
59
60
average speech user / BS

Fig.2

INTERNATIONAL SEARCH REPORT

International Application No
PCT/IT 01/00240

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H04Q7/38

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H04Q

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X A	US 5 487 174 A (PERSSON BENGT Y) 23 January 1996 (1996-01-23) column 4, line 42 -column 5, line 43 column 7, line 56 -column 10, line 48 column 15, line 53 -column 17, line 52 ---	1-4,8, 10-13,17 5,14
A	US 5 781 861 A (KANG CHANG-SOON ET AL) 14 July 1998 (1998-07-14) column 2, line 26 -column 3, line 4 column 4, line 62 -column 6, line 42 -----	5-8, 14-17

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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"A" document defining the general state of the art which is not considered to be of particular relevance

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Date of the actual completion of the international search	Date of mailing of the international search report
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